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RESEARCH ARTICLE

Mortality in Galla Goat Production System in Southern Rangelands of Kenya: Levels and Predictors

John Kibara Manyeki* • Bosco Kidake • Benson Mulei • Simon Kuria

Kenya Agricultural and Livestock Research Organization, Arid and Range Lands Research Institute, Makueni/Kenya

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ABSTRACT

Herd health and adaptability are of concern in animal production in the tropics because of the persistent exposure to multiple stresses of low quality and quantity feeds, heat stress, high disease, and parasite incidences, poor husbandry, and breeding practices; the combined effects of these factors is high livestock mortality. High health-related mortality has been frequently reported as the major impediment to livestock production and thus the aim of this article is to investigate the vital infectious diseases and non-infectious factors that account for the majority of deaths which is crucial in determining mortality control strategies. The study applies a descriptive, Kaplan-Meier method, and truncated regression analysis using an eight-year retrospective data spanning from 2014 to 2021 was applied for this analysis. The results indicate infectious diseases as the most important cause of Galla goat mortality. The mean monthly and annual mortality rates are higher and the pre-weaning mortality of Galla goat appeared to be one of the major constraints hampering the development of replacement stock. The risk factors considered for high mortality were the age and sex of the kids. Among the infectious diseases analyzed, bacterial, parasitic, and non-specific infectious diseases were identified as the important causes of Galla goat mortality, while the non-infectious conditions included malnutrition and thermal/cold shock. The analysis provided an improved insight into animal-health-related factors which once addressed could reduce mortality and hence optimize animal husbandry performance in Galla goat production systems. Interventions in Galla goat health and husbandry are recommended to control kids' mortality.

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Introduction

The development of the livestock sector in Kenya has a considerable prospective opportunity for smallholder farming and income generation and may contribute significantly to poverty alleviation and food and nutrition security. This is because Kenya holds a huge potential for livestock development as about two-third of the total landmass is arid and semi-arid lands (ASALs) suitable for livestock rearing, while only one-third is agriculturally productive and includes the Kenyan highlands, coastal plains, and the lake regions. Disappointingly, only 50% of the ASALs carrying capacity of the land is currently being exploited (Odhiambo, 2013). Similarly, livestock production and productivity are also low and this can partly be attributed to the poor genetic potential of indigenous breeds, frequent seasonal drought, feed shortage in quantity and quality, high prevalence of animal diseases, poor infrastructure, and access to animal health services. Among the highlighted contributing parameters to low productivity, animal disease mortality data are largely lacking and are said to influence substantially the high livestock losses experienced (Mulei et al., 1995; Nkedianye et al., 2011).

Livestock mortality is considered one of the major constraints to herd expansion and genetic improvement. Specifically, as reported by many scholars, in any livestock

* Corresponding author
E-mail address: manyekijk@gmail.com

production enterprise, the survival of female young ones is required for herd expansion and breed improvement, while that of male young ones is used as a source of income from sales or as draught animals (*e.g.*, Carles & Schwartz, 1982; Gitau et al., 1994; Thumbi et al., 2013). Since mortality is inevitable for all livestock production systems, understanding its extent and causes at the herd or sector level is a challenging phenomenon (Mayer et al., 2012). Interventions aimed at reducing livestock mortality require specific data on the important causes of mortality (Mayer et al., 2012). For these reasons, an accurate quantitative livestock-health-related mortality within and across different livestock production systems (Aganga et al., 2005; Ershaduzzaman et al., 2007; Fentie, 2016) provides a foundation for understanding, extension, and further research.

Since high livestock-health-related mortality has been the major impediment to various livestock production and thus an indicator of low production and productivity, understanding the vital infectious and non-infectious diseases that account for the majority of deaths is crucial in determining mortality mitigation strategies. Under the maintained hypothesis that production behaviour is driven by a firm's objective of maximizing the profits it enjoys, one cannot ignore the effect of mortality on livestock production. Retrospective studies addressing the causes of death in Galla goats in Kenya are scarcely making it hard in the allocation of limited funds available for such control strategies, and this formed the basis of this analysis. Neither assumption made in the previous studies under similar terrain (Aganga et al., 2005; Ershaduzzaman et al., 2007; Fentie, 2016) can be expected to hold in the more tropical regions of Kenyan ASALs, where livestock are routinely subjected to long periods of nutritional stress and high disease incidences. We, therefore, hypothesized an econometric relationship would be required for these areas. Specifically, this article aimed at addressing this gap of information by estimating the Galla goat mortality rates as well as identifying the infectious and non-infectious factors associated with mortality which would be a target for programs aimed at reducing mortality in rangelands of Kenya employing an econometric technique.

Materials and Methods

Study Area and Animals

The study was carried out at the Kenya Agricultural and Livestock Research Organization (KALRO), Kiboko research station (KALRO-Kiboko, henceforth) of the Arid and Range lands research institute. KALRO-Kiboko was established in 1969 as a research station charged with the mandate of undertaking a national range of research which entailed undertaking work on applied research on specific constraints affecting rangeland productivity and eventually developing appropriate technologies, recommendations, techniques, and knowledge systems that would solve/mitigate production set-backs. The station is an establishment under KALRO and its suitability for livestock production is typical because it is located in ecological zone IV-V which, generally, is not suitable for arable agriculture. The station is located at Kiboko in Makindu Sub-County of Makueni County, about 160 km SE of Nairobi, along Mombasa-Nairobi Highway, and lies between latitude 2° 10' and 2° South and longitude 37° 40' and 37° 55' East.

KALRO-Kiboko research station has the potential to deal with the production of cattle, goats, sheep, and camels, but currently, livestock kept consists of cattle (Boran, Small East African Short Horne Zebu, and their crosses) and Galla goat targeted mainly for red-meat production and quality breeding stock. In the context of this article, the study animals consisted of Galla goats which were collected across Kenyan rangelands with an annual mean population of 534 (with a standard deviation of 71.2) during the study period (2014-2021). Thus, the data were deemed be a representative of the many Galla goat production zones not only in Kenya but also in the East Africa countries. The high standard division implies high volatility of livestock production across years and seasons. Females are more than males with a percent proportion of 66.2% and 33.8%, respectively, for herd build-up for breed selection and income generation, respectively.

Data Type

The analysis aims to assess the various causes of death of Galla goat as recorded by the department of livestock in the KALRO-Kiboko research station from 2014 to 2021 (8 years). Animal health officers frequently visit goat *bomas* for disease diagnosis, treatment, and health-related data capture. Mortality is in cases of death and their causes, and all the cases are recorded and uploaded in the MS Excel data sheet. Nonetheless, the results can, however, be difficult to interpret in the absence of information on the typical pattern of losses in the enterprise, therefore, the first step was to retrospectively compile monthly records of animal stock, type of diseases treated, death and any causes for animal disappearances during the period of study. The second step was to categorize the different infectious and non-infectious conditions that cause mortality and analyze to predict the probability of the occurrences.

Infectious factors were categorized as protozoan (anaplasmosis, babesiosis, ECF, trypanosomosis), bacterial (pneumonia, enteritis, septicemia/toxemia, enterotoxaemia, scours, anemia, CCPP, metritis, pyometra, sinusitis, myocarditis, etc.), parasitic (represented by haemonchosis and haemonchus), Rickettsial diseases (heartwater/cowdriosis) and other conditions (such as bloat, calculi, uremia, hardware disease, hepatitis, senescence, percadisise, trauma, and viral conditions like rabies), and non-specified disease causes. Non-infectious causes included shock (hypothermic and cardiogenic), traumatic injuries, predation, plant poisoning, malnutrition, dystocia, premature birth (abortions and stillbirth), and postnatal/congenital defects. The sample comprises 96 observations, with minimal outliers which were omitted during analysis.

Data Analysis

Descriptive statistics, Kaplan-Meier method, and an econometric model approach were employed to analyze data using MS Excel and STATA statistical software (StataCorp, 2016). Under descriptive statistics, causes of animal mortality were compiled and the percentage contribution (proportion) of each cause for mortality was calculated and presented. Additionally, the study also involved computing the probabilities of Galla goat mortality at a certain point of time using the widely used Kaplan-Meier nonparametric method (Kaplan & Meier, 1958; Adelöf et al., 2021). The survival probability of Galla goat at any particular period, S_p was calculated by the formula given below;

$$S_p = \frac{N_S - N_D}{N_S} \tag{1}$$

where, N_S: Number of Galla goats lining at the start and N_D: Number of Galla goats that died.

Since the flock size is dynamic and usually births are experienced at any time, this means that they become a part of the study later. To some cases, there is often a shorter observation period and those goats may or may not experience death in that short stipulated time. However, we cannot exclude those goats since otherwise sample size of the study may become small. The Kaplan-Meier method allow us to compute the survival over time in spite of such difficulties associated with subjects or situations (Goel et al., 2010; Grzesiak et al., 2022). Therefore, for each time interval, survival probability was calculated as the number of Galla goats surviving divided by the number of Galla goats at risk. The total probability of survival till that time period was calculated by multiplying all the probabilities of survival at all-time intervals preceding that time (by applying law of multiplication of probability to calculate cumulative probability) [Kaplan & Meier, 1958; Grzesiak et al., 2022]. Then, the probability of Galla goat dying (cumulative mortality) is 1 (one) minus the probability of Galla goat survival (cumulative survival). Galla goats who have died or sold out are not counted as “at risk”, hence are considered “censored” and are not counted in the denominator.

The other phase of analysis involved the determination of the effect the various causes have on mortality. Since econometric models offer estimates of actual values for forecasted variables and indicate both the direction and magnitude of change, then it was found appropriate to determine the effect of infectious and non-infectious factors on Galla goat mortality for uncensored data. In this paper, the outcome measure of interest was mortality, defined as any death of a study animal occurring during the period of observation and attributed to an infectious and non-infectious disease cause. The independent variables included infectious factors being the protozoan, bacterial, parasitic, Rickettsial diseases and other conditions, and non-infectious factors categorized as a shock, traumatic injury, predation, plant poisoning, malnutrition, dystocia, premature birth, congenital/postnatal defects, and non-specified causes. Truncated regression of the normal distribution was performed to identify risk factors for Galla goat mortality. The truncated model was selected because sample truncation is a pervasive issue in quantitative animal sciences, particularly when using observational data such as the data employed in this study (Abot, 2020; Ouédraogo et al., 2022). Truncation reduces the variance compared with the variance in the untruncated (Heckman, 1979; Dongfang et al., 2017). A truncated regression is one in which the values of the explanatory variables are observed only if the value of the dependent variable is observed and, thus following Greene (2010) and Reinhammar (2019), a truncated regression (at zero) was specified as;

$$y_i = X_i'\beta + \varepsilon_i, i = 1, \ldots., n \tag{2}$$

$$\varepsilon_i \sim iidN\ (0, \sigma^2) \tag{3}$$

where, y_i and x_i are observed number of livestock death and risk factors causing mortality respectively, the truncated form below for $y_i > 0$. The factors related to infectious and non-infectious diseases were considered independent variables (x_i) and livestock death as dependent/outcome variable (y_i). Term ε_i is the random error associated with random shocks, not under the control of economic agent *i*, and in this case capture weather changes or any economic adversity. The X-vector parameter estimate for mortality level ($\hat{y}_i$), is expected to have a positive sign, which implies the corresponding variable would increase the level of Galla goat mortality rate. The results of the analyses were final truncated models including all variables (risk factors) significantly associated with Galla goat mortality and the estimation was carried out using the maximum likelihood estimation (MLE) procedure. The use of the MLE technique makes sense because the error terms nested on these equations are assumed to follow a certain distribution, and our goal is to obtain the “most likely” estimate rather than one which minimizes the sum of squares as is the case with ordinary least square.

Results and Discussion

Descriptive Statistic

Descriptive and analytical statistics were used and the causes of Galla goat mortality were compiled, and the percentage contribution (proportion) of each cause for mortality was calculated and presented in Table 1. Mean annual mortality was determined by dividing the number of deaths by the number of alive Galla goats within a particular study period and was expressed as;

$$OMR\ (\%) = \frac{N_{DP}}{N_{SP}}\ x\ 100 \tag{4}$$

where, *OMR*: Overall mortality rates, N_{DP}: Number of deaths per period, and N_{SP}: Number of stock within each period.

As indicated in the Table 1, the Galla goat is characterized by high mortality. The estimated mean monthly and annual mortality are high ranging between 8.86-52.4% (with an annual average of 25.99%). This high mortality rate is comparable to findings by ILCA (1990) that ranges between 25-35% for African sheep and goats, and Otte and Chilonda (2002) mortality risks in all age groups of lamb and kids of around 27-28 percent. Although comparable under the African setup, these mortality rates are more than five times (*i.e.*, 25.99/5) what is observed in most well-managed dairy systems in the developed countries where the all-cause mortality rates are frequently reported to be below 5% (Svensson et al., 2006; Gulliksen et al., 2009). Even though Galla goats are considered well adapted to survive in environments of high disease pressure (Ngila et al., 2016; PACIDA, 2020), mortality rates as observed in this study suggest significant losses.

Table 1. Estimated mean monthly and annual mortality for Galla goat during the 2014-2021 study period.

Years	Mean Monthly Mortality	Annual Mortality Rate
2014	16.9	42.8
2015	9.31	25.9
2016	5.23	20.3
2017	2.62	8.86
2018	5.77	15.1
2019	13.8	34.9
2020	8.4	24.5
2021	18.17	52.4
Overall average	8.88	25.99

The statistical analysis of mortality rates recorded in the Galla goat production system for the period of 2014-2021 was skewed and showed a clear influence of age and sex as shown in Table 2. A higher mortality rate was reported in the young ones (kids below four months) and decreased with increasing age. This result concurred with a recent finding by Alemnew et al. (2020) who observed that as the age of kids increased, the number of kids who died decreased. Early mortality for kids during the first four-month of life accounted for 44.6% of the total mortalities and was particularly high in female kids than in the males. The results contradict the finding of Perez-Razo et al. (1998), Aganga et al. (2005), and Hailu et al. (2006) who recorded higher mortality for male kids compared to females. Comparably, the same pre-weaning kid mortality of about 46.8% was observed by Petros et al. (2014) among the goat kids in Ethiopia, and age in months had a significant effect. The result also concurred with Girma et al. (2011), where higher mortality rates were recorded in females than in males in Arsi-Bale kids kept in a similar environment.

Table 2. Estimated Galla goat mortality distribution by age category.

Age category	Percent Proportion of the Deaths		
	Percentage Proportion of the Total	Male (%)	Female (%)
Kids (<4 months)	44.6	48.5	51.5
Weaners (5-9 months)	27.1	46.2	53.8
Yearlings (10-12 months)	7.61	41.2	58.8
Mature (1-2 years)	4.32	41.4	58.6
Mature (3-4 years)	3.87	3.85	96.2
Mature (5-6 years)	5.51	0	100
Mature (7-8 years)	6.11	2.44	97.6
Mature (>8 years)	0.894	0	100
Total proportion (in %)	100	22.9	77.1

The percentage proportion for the birth-to-weaning contributed to the highest mortality (about 44.6%) in the KALRO-Kiboko Galla goat production system. Similar high mortality of about 67% for calves within a week of their birth (Bunter et al., 2013), with the cause of death most frequently recorded as unspecific. However, there was no significant difference in the number of deaths after one year of goat life. The high mortality of 44.6% of the goat during the first four-month reported in the present study means the ranch cannot raise enough stock to replace the loss, let alone expand the herds and, therefore, more attention to kids' management in the first months of life is a critical prerequisite. This is because a reduction in kids' mortality would translate into an increase in flock size and consequently the increase in male and culled offtake.

Overall, the descriptive statistics show high female mortality which is also inversely related to age. Since the herd composition differed somewhat between the sexes (with the female being two-third of the total population), the high female mortality rates could thus reflect differences in herd composition. The low mortality observed in males might also be because the males are frequently culled upon attaining one year of age to keep the limited number of males for the breeding purpose for a limited period. A similar result was observed in the Mlimbe et al. (2020) study.

Kaplan-Meier Estimates

The Kaplan-Meier estimates for mortality are displayed in Table 3. Looking at the table, the year was divided into twelve intervals, corresponding to the times of death of the 119 Galla goats. The average number of Galla goats was about 410, while a total of 194 goats exited the flock through death or sale. This translate to about 47.3% of the total number of observations that were censored. Based on the Kaplan-Meier functions, the cumulative survival decline could be observed and this translate to an increase in the Cumulative mortality for the entire period of about 29%. The proportion surviving Galla goat on this day seems to be relatively high and ranges from 0.922 to 0.991. comparable survival probability for cows culled for different reasons was observed in Grzesiak et al. (2022) study.

Table 3. Kaplan-Meier estimate for Galla goat.

Time	Total Flock	Births	Sales	Deaths	Proportion surviving on this day	Cumulative survival	Cumulative mortality (CM)
January	458	8	1	8	0.983	0.983	0.017
February	457	16	0	7	0.985	0.967	0.033
March	466	11	9	9	0.981	0.949	0.051
April	459	3	10	6	0.987	0.936	0.064
May	446	17	4	5	0.989	0.926	0.074
June	454	7	3	4	0.991	0.918	0.082
July	454	5	15	6	0.987	0.906	0.094
August	369	20	13	12	0.967	0.876	0.124
September	363	3	2	17	0.953	0.835	0.165
October	347	8	1	27	0.922	0.770	0.230
November	327	14	0	17	0.948	0.730	0.270
December	324	43	9	9	0.972	0.710	0.290

CM = 1-cumulative survival.

The causes of mortality in Galla goat and their relative contribution to the mortalities based on the data collected during the 2014-2021 study period are presented in Table 4. A more in-depth analysis of individual causes of mortality in the Galla goat production system showed that infectious diseases contributing 65.69% of the total flock loss is the largest single factor to the immense flock mortality, while non-infectious conditions contributed only 34.3%. Among the infectious causes of Galla goat mortality identified, bacterial (mainly represented by Contagious Caprine Pleuro-Pneumonia/CCPP, enteritis, enterotoxaemia) was the major problem, followed by the parasite (mainly represented by haemonchosis). The findings of this study are in agreement with Tibbo (2000)'s findings for goats in Awassa Zuria woreda in south western parts of Ethiopia where diseases and infectious parasites were found to be the main causes of high mortality and morbidity. Similarly, Tembely (1998) observed that parasitic and bacteria diseases (such as CCPP and respiratory disease syndrome) were major causes of morbidity and mortality of small ruminates in Ethiopia. In the current study, considerable mortality was also reported related to general disease syndromes (non-specific) such as tumors, anorexia, and sudden deaths. Sudden deaths were deaths with unrecognized syndromes. Rickettsial infections specifically heart water/cowdrosis and dystocia cases were few during the study period. The limited capacity of the existing institutional veterinary officers to serve the vast livestock population in the KALRO-Kiboko station throughout the study period may have worsened the situation leading to the higher mortalities recorded.

The contribution of non-infectious conditions to Galla goat mortality was higher for malnutrition (15.9%) and shock (6.13%). Similar high mortality losses associated with malnutrition were reported by Ocaido et al. (2009) and Mlimbe et al. (2020) in Uganda and Tanzania, respectively. For Galla goat production, predators such as hyenas, cheetahs, and jackals were implicated as important causes of loss which concurred with the finding by Fentie (2016) among the small ruminants in Ethiopia.

Overall, the results show that females are more susceptible to infections and non-infectious factors than males which were the general observation in Kocho (2007)'s study. However, males are highly prone to death from protozoa and parasitic infectious diseases than females.

Table 4. Main causes of Galla goat mortality.

Causes	% Proportion	Male	Female
Infectious factors			
Protozoa	1.31	0.729	0.584
Bacteria	37.8	14.6	23.2
Parasite	9.49	5.11	4.38
Rickettsial diseases	3.65	0.729	2.92
Non specific	8.17	2.04	6.13
Other diseases	5.26	1.75	3.51
Non-infectious factors			
Dehydration	0.876	0.146	0.729
Injury	0.876	0.438	0.438
Predation	4.23	1.31	2.92
Plant poisoning	5.41	2.48	2.92
Malnutrition	15.9	7.59	8.32
Shock	6.13	2.92	3.21
Dystocia	0.146	-	0.146
Congenital defects	0.729	0.292	0.438

Econometric Estimation of the Causes of Livestock Mortality

For a better understanding of the underlying causes of mortality, a truncated model was fitted to investigate the direction and magnitude of the various infectious and non-infectious factors that cause Galla goat mortality. The truncated regression analyses examined all possible interactions among variables and death as the outcome variable. However, before estimating a truncated regression model, one has to address the problem associated with multicollinearity. The test of multicollinearity was done through the computation of a collinearity diagnostic measure referred to as variance inflation factors (VIF). As presented in Table 5, all the independent variables exhibited $VIF_i < 5_i$ (with an average VIF of 1.27), it was concluded that there was no multicollinearity and therefore all the variables were eligible for inclusion in the model estimation. The same conclusion of no multicollinearity can be arrived by checking the coefficient for the collinearity diagnosis. All independent variables are very not highly correlated to one another (r>0.5) with the Eigen values & condition index computed being less than 10, an indication of stability (Table 6). The estimates of sigma square (σ^2) are significantly different from zero at a 1% level of significance, implying a good fit of the specified distribution assumptions of the error term and the Wald Chi-square value showed that statistical tests are highly significant (p<0.000), suggesting that the model had strong explanatory power.

Regarding the various covariant variables included in the model and displayed in Table 5, all variables assumed the expected positive sign. The disease was identified as the major cause of mortality in the Galla goat production system of the study area. In the present study, the magnitude of goat mortality attributed to diseases is 0.768 which is statistically significant (at a 1% level), and the contribution to the overall mortality is about 65.69%. Based on the magnitude of the coefficient on the disease variable, while holding other variables constant, a unit improvement in animal health care would reduce Galla goat mortality by 18.94% (*i.e.*, 24.7×0.768). The high proportion of kid mortality (of 44.6%) due to diseases was also reported in Botswana (Aganga et al., 2005) and a similarly higher percentage contribution of diseases to kid mortality (of about 63%) was reported in Black Bengal Kids in Bangladesh (Ershaduzzaman et al., 2007). The high-risk factor associated with diseases indicates that the most important area of intervention in reducing Galla goat mortality should be health management.

Among the non-infectious conditions associated with Galla goat mortality, malnutrition though highly significant accompanied by a relatively high percent contribution, the magnitude was lower than that of congenital defects and dehydration. This finding concurred with that of Fentie (2016), who found malnutrition (which was presented as feed shortage) as one of the major problems causing mortality in young stock across all species. Malnutrition can be a result of insufficient milk/colostrum in the first 24 hours of birth which is critical for passive transfer of immunity to the kids, this might be due to poor mothering ability by the dams and the seasonal shortage of feed during dry periods. Galla goats mainly depend on browsing, and the provision of supplementary feed is very limited. Accordingly, the high disease-related mortality rate observed can be aggravated by the effect of malnutrition in terms of feed and milk shortages that could compromise the immunity of young stock and expose them to diseases. The effects of mean dystocia were however lost when infection data was included, indicating that this factor may be related to the infectious diseases. Exposure to predators and plant poisoning had only a marginal effect on Galla goat mortality and traumatic injuries showed no statistically significant effect on mortality although the percentage contribution was higher than that of congenital defects. Similar to Fentie (2016)'s findings, in the case of kids, the contribution of predators (hyena, cheetah, etc.) and injury (physical damage) in herds where young and adult animals share the same barns were important causes of mortality.

Table 5. Causes of Galla goat mortality and percentage contribution (proportion).

Variables	Coefficient	Standard Deviation	Proportion	Variance Inflation Factor (VIF)
Diseases	0.768***	0.0259	65.74	1.20
Congenital defects	0.285***	0.0449	0.729	1.06
Dehydration	0.185**	0.0768	0.876	1.04
Dystocia	0.000	(omitted)	0.146	-
Injury	0.113	0.0839	0.876	1.04
Predation	0.0536*	0.0342	4.234	1.84
Plant poisoning	0.0504***	0.0185	5.41	1.15
Malnutrition	0.0787***	0.00702	15.9	1.39
Shock	0.0501***	0.00528	6.13	1.46
Constant	0.527***	0.0549	-	-
sigma (σ^2)	0.173***	0.0173	-	-
Wald chi2	1476.06***	-	-	-
Log-likelihood	16.7	-	-	-
Mean VIF	-	-	-	1.27

***, **, * implies significance at 1%, 5%, 10%, respectively.

Table 6. Collinearity diagnostics.

	Eigen Value	Condition Index
1	2.9090	1.0000
2	1.3512	1.4672
3	1.0450	1.6684
4	1.0036	1.7025
5	0.9684	1.7332
6	0.8842	1.8138
7	0.6564	2.1052
8	0.5353	2.3310
9	0.3829	2.7563
10	0.2640	3.3192
Condition Number		3.3192

Eigen values and condition index computed from scaled raw sscp (w/ intercept) Det (correlation matrix) = 0.4408.

Having confirmed that disease-related syndromes were the main cause of mortality, an attempt was made to identify which particular disease conditions significantly contribute to Galla goat deaths. The results of this analysis is displayed in Table 7. Again all the non-infectious conditions were subjected to a multicollinearity test and all variables exhibited $VIF_i < 5_i$ (with an average VIF of 1.24), implying there was no evidence of multicollinearity. The collinearity diagnosis test (Table 8) indicated that all independent variables are very not highly correlated to one another (r>0.5) with the Eigen values and condition index computed being less than 10, an indication of stability. The estimates of sigma square (σ^2) was significantly different from zero at a 1% level of significance, indicating a good fit of the specified distribution assumptions of the error term and the Wald Chi-square value showed that statistical tests are significant (p<0.000) suggesting that the model had strong explanatory power.

With regards to infectious diseases included in the model, the analysis shows robust results as all were statistically significant at 1 and 10% levels. Among the infectious diseases investigated, bacteria majorly represented by pneumonia, enteritis, septicemia, enterotoxaemia, and CCPP were noted as the first major disease problem of goats, followed by parasites mainly haemonchosis. The percentage proportion mortality as a result of bacteria was 57.56%, and 14.44% was related to parasite problems. Parasites causing mortality in this study are in agreement with Tibbo (2000)'s finding for goats in Awassa Zuria woreda in south western parts of Ethiopia and Aganga et al. (2005) in Botswana. Equally, an in-depth study by Kocho (2007) also observed parasites across the different sites of Southern Ethiopia were not significantly different (p>0.05) which depict that it is a major cross-cutting impediment to the goat production in the region. Among the diagnosed diseases, rickettsia infections majorly represented by heartwater (or cowdrosis) disease had the highest magnitude, hence, its effects should be reduced to the bare minimum. Heartwater has been reported throughout sub-Saharan Africa (Uilenberg, 1983) and in Mozambique, Asselbergs et al. (1993) observed the disease to occur throughout the country and mainly during the rainy season.

Table 7. Disease syndromes related to Galla goat mortality.

Variables	Coefficient	Standard Deviation	Proportion	Variance Inflation Factor (VIF)
Protozoa	0.109*	0.0795	2.00	1.19
Bacteria	0.106***	0.00883	57.6	1.35
Parasite	0.0633***	0.0185	14.4	1.52
Non specific	0.121***	0.0295	12.4	1.23
Other diseases	0.152***	0.0261	8.01	1.12
Rickettsia diseases	0.196***	0.0409	5.56	1.07
Constant	0.882***	0.0739	-	-
Sigma (σ^2)	0.268***	0.0289	-	-
Wald chi2	375.38***	-	-	-
Log-likelihood	-4.4217	-	-	-
Mean VIF	-	-	-	1.24

***, **, * implies significance at 1%, 5%, 10%, respectively.

Table 8. Collinearity diagnostics.

	Eigen Value	Condition Index
1	3.3195	1.0000
2	1.0363	1.7898
3	0.7178	2.1505
4	0.6518	2.2568
5	0.5437	2.4708
6	0.4208	2.8085
7	0.3101	3.2720
Condition Number		3.2720

Eigen values and condition index computed from scaled raw sscp (w/ intercept) Det (correlation matrix) = 0.4114.

Conclusion

This study has investigated mortality in Galla goat and identified the main causes of death and the risk factors associated with infectious and non-infectious disease mortality. The all-cause mortality rate was estimated at 25.99% per 100 animal risk years with an annual cumulative mortality of 29%. The mortality contribution to infectious diseases was estimated at 65.69% risk years. This study has also indicated that mortality in kids born alive is likely to be above 44 percent and may represent the high loss in Galla goats due to husbandry practices of the KALRO-Kiboko research station. The risk factors considered for high mortality were the age and sex of the kids. The pre-weaning mortality of Galla goat appeared to be one of the major constraints in the KALRO-Kiboko farm, hampering the development of replacement stock. The critical time for higher goat mortality in this production system was during the first four months of life-extending up to the ninth month of age. Therefore, for an efficient Galla goat production system, the survival of female kids is required for herd expansion and breed improvement, while that of male kids is used as a source of income from sales; so the mortality of kids, in general, should be reduced to the bare minimum.

Concerning infectious and non-infectious conditions influencing mortality, disease and malnutrition appeared to be the most important causes of Galla goat mortality. Among infectious diseases, bacterial diseases, parasitic conditions, and non-specific diseases were the most common challenges of raising Galla goat on the KALRO-Kiboko farm. Overall, infectious diseases contribute to high mortalities in Galla goats, and they reduce animal performance. However, many of the health problems of Galla goat can be controlled by excellent early nutrition and management. For instance, as observed in this study, kids were at higher risk of dying if they were not separated from adult animals because the separation of sick animals from the flock contributes to kid survival as it minimizes the risk of transmission of contagious diseases. Modest interventions on the significant flock impediments, for example, minimizing flock loss through disease control and protection against predators and proper feeding to curb the effect of malnutrition could potentially boost the flock performances. The veterinary service needs to provide strategic disease prevention, control, and treatment measures. Future studies should investigate the effects of farm management practices on Galla goat mortality which together with the insight provided by this study will help in constructing a conceptual comprehensive stock-and-flow model of a representative Galla goat production system for Kenya. The idea is to develop a holistic systems model for Galla goat production in an extensive Kenyan rangeland environment as it is in the other part of the world.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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